Probing neutrino nature with the LEGEND experiment

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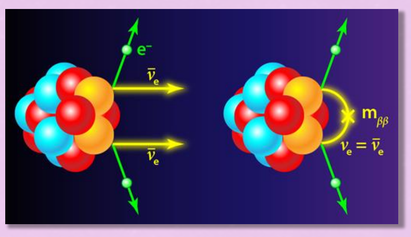
LEGEND Large Enriched Germanium Experiment for Neutrinoless ββ Decay

Why does matter dominate over antimatter in the Universe? Despite particle creation and annihilation occur in a balanced manner, the Universe is made almost entirely of matter. Studying neutrinos might lead to the solution of this problem. These elusive particles could be their own antiparticles, violating lepton-number conservation. Built at Laboratori Nazionali del Gran Sasso, Italy, the LEGEND experiment explores the Majorana nature of neutrinos by searching for the rare **neutrinoless double beta decay**.

Physics Goal: Probing the Majorana nature of neutrinos by observing the neutrinoless double beta decay in high-purity germanium (HPGe) crystals enriched in ^{76}Ge.

- Double beta decay ($2\nu\beta\beta$), expected in the SM and observed: two neutrinos emitted $^{76}Ge \rightarrow {}^{76}Se + 2e^- + 2\overline{\nu_e}$ ($\Delta L = 0$)
- Neutrinoless double beta decay ($0\nu\beta\beta$), beyond SM and not observed so far: no neutrinos emitted $^{76}Ge \rightarrow {}^{76}Se + 2e^-$ **($\Delta L = +2$)**

Lepton-number violating process!

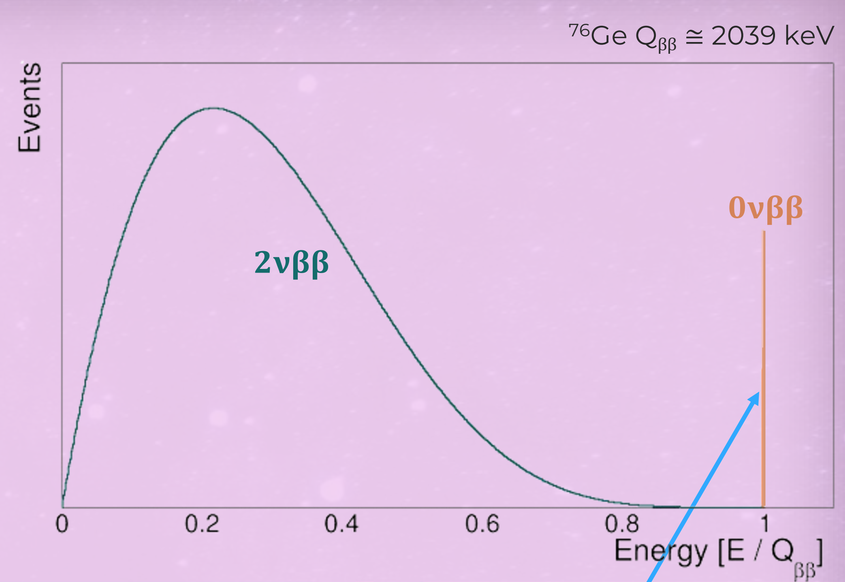


Sensitivity aim:

- LEGEND-200 (5 yr data-taking): decay half life of $T_{1/2} > 10^{27}$ yr
- LEGEND-1000 (10 yr data-taking): decay half life of $T_{1/2} > 10^{28}$ yr

Very rare event!

Results of the first year of LEGEND-200 data-taking:
Decay half life of $T_{1/2} > 1.9 \cdot 10^{26}$ yr
Background index (90% C.L.) = (5.3 ± 2.2) 10^{-4} counts/(keV kg yr)



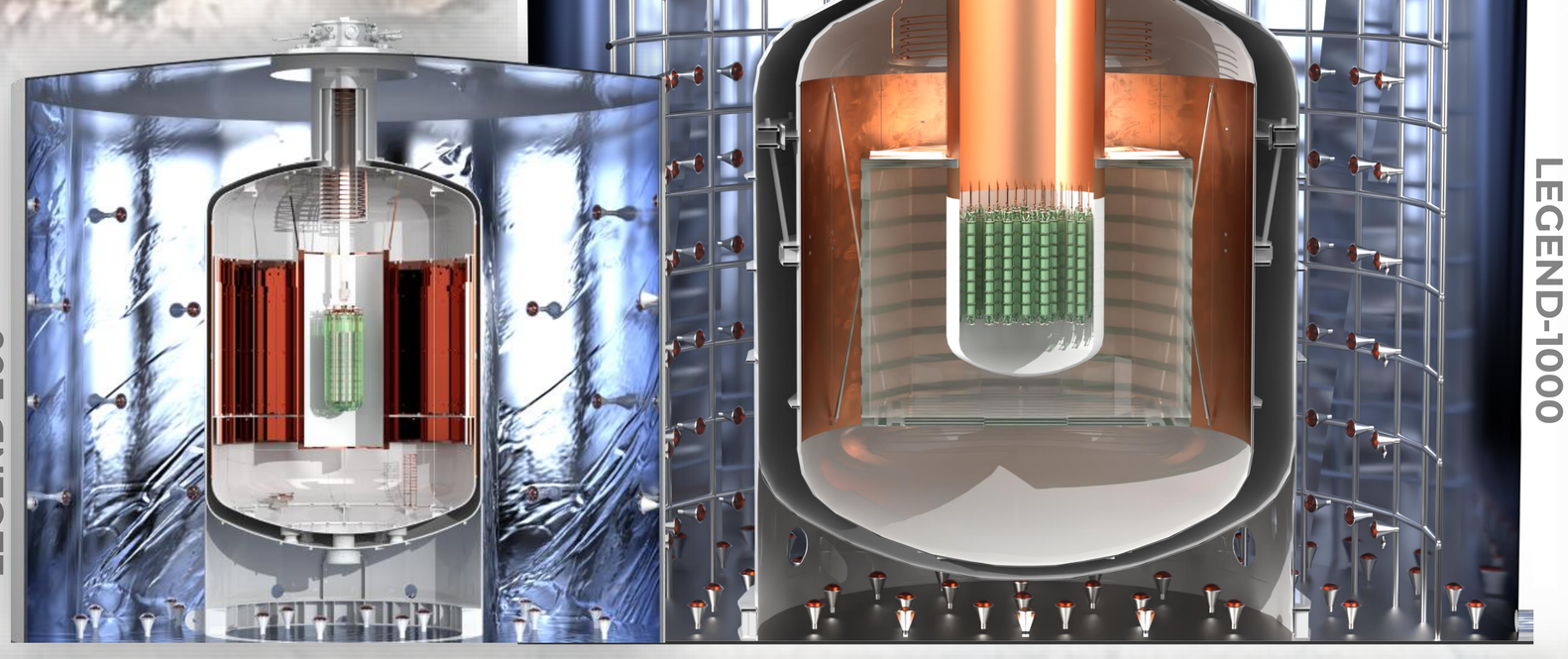
Lower background + Excellent energy resolution (FWHM ~0.1% @ $Q_{\beta\beta}$)

Higher chance of discovery

Gran Sasso Mountain overburden (1.4 km) provides shielding from atmospheric muons

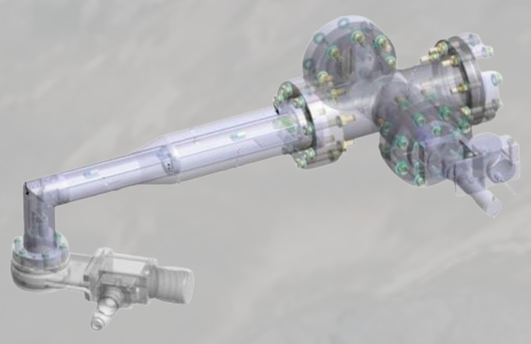
LEGEND-200
Currently taking data with ~140 kg of ^{76}Ge detectors immersed in 63 m^3 of liquid argon

LEGEND-1000
Planned to employ 1000 kg of ^{76}Ge in underground liquid argon. Phased commissioning expected to start in 2030



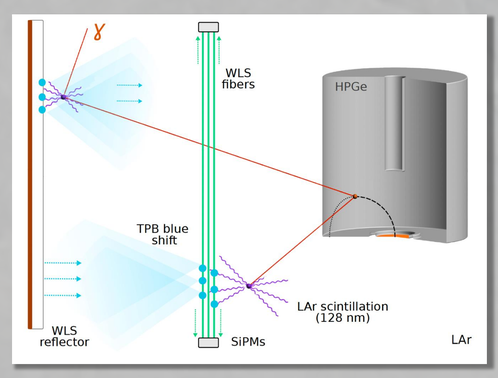
Our group's focus areas:

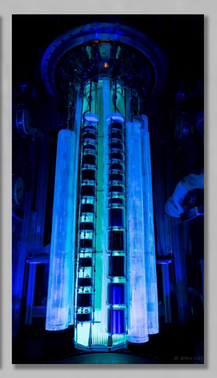
1. Source Insertion System to calibrate detectors



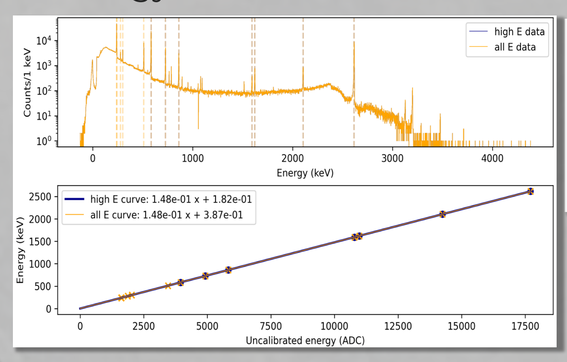
2. Wavelength-Shifting Materials Characterization

- Wavelength-shifting **reflectors** surround the **fibers** to enanche light collection
- Detector holders, made of polyethylene naphthalate, shift **VUV light**

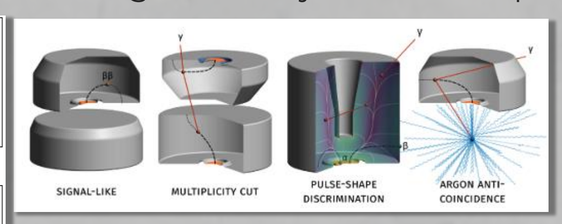


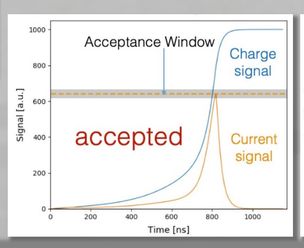


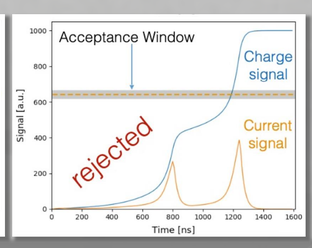
3. Energy Calibration



4. Background Rejection + Deep Learning







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